Agrovoc descriptors: lycopersicon esculentum, tomatoes, quality, storage, temperature, storage losses, weight, colour

Agris category code: Q04, J11

COBISS Code 1.01

Comparative study of quality changes in tomato cv. 'Malike' (*Lycopersicon esculentum* Mill.) whilst stored at different temperatures

Dragan ŽNIDARČIČ[1], Tomaž POŽRL[2]

Received June 26, 2006; accepted August 18, 2006.
Delo je prispelo 26. junija 2006; sprejeto 18. avgusta 2006.

ABSTRACT

The objective of this study was to compare the effects of storage conditions on the indeterminate tomatoes (*Lycopersicon esculentum* Mill.) cv. 'Malike'. Fruits were stored at 5 °C and 10 °C for up to 28 days; to extend their post-harvest life and maintain fruit quality parameters. The weight loss, soluble solids, titrable acidity and skin colour components of the fruits were recorded weekly. The weight loss of tomatoes was almost linear at both storage temperatures. Fruits stored at 10 °C lost weight faster than those stored at 5 °C. Storage at lower temperature tended to increase tomato longevity. At the end of the storage period the fruits stored at 5 °C experienced a weight loss of 13.6 % (after 28 days), while those stored at 10 °C showed values of 14.2 % (after 21 days). Soluble solids increased slightly from 5.06 % to 6.92 % at 5 °C (during 28 days period) and from 5.06 % to 6.26 % at 10 °C (during 21 days period). There were only slight changes in soluble solids content during the stored period studied, as well as non-significant differences between the two temperatures. Changes of titrable acidity during storage were relatively small. After seven days the content of titrable acid started to decrease at both temperatures. There was no significant skin colour difference between the tomatoes maintained at different temperatures.

Key words: *Lycopersicon esculentum*, tomato, storage, temperature, weight loss, colour, chemical composition

IZVLEČEK

PRIMERJALNA ŠTUDIJA KVALITATIVNIH SPREMEMB PARADIŽNIKA CV. 'MALIKE' (*Lycopersicon esculentum* Mill.), SKLADIŠČENEGA PRI RAZLIČNIH TEMPERATURAH

Cilj raziskave je bil primerjati, kako razmere skladiščenja vplivajo na indeterminantni paradižnik (*Lycopersicon esculentum* Mill.) cv. 'Malike'. Plodovi so bili skladiščeni 28 dni pri temperaturi 5 °C in 10 °C z namenom, da bi podaljšali trajnost plodov in hkrati obdržali njihovo kakovost. V enakih tedenskih intervali smo merili izgubo teže, vsebnost suhe snovi, vsebnost skupnih kislin in barvo kože plodov. Izguba teže je bila skoraj linearna pri obeh temperaturah. Plodovi, skladiščeni pri 10 °C, so težo izgubljali hitreje kot tisti, skladiščeni pri 5 °C. Ob skladiščenju pri nižji temperaturi se je pokazala težnja po podaljšanju življenjske dobe plodov. Na koncu poskusa smo ugotovili, da so plodovi skladiščeni pri 5 °C izgubili 13,6 %

[1] M. Sc. Agr., SI-1111 Ljubljana, Jamnikarjeva 101, P. O. Box 95,
[2] M. Sc. Food. Tech., ibid,

teže (po 28-ih dneh), medtem ko so tisti pri 10 °C izgubili 14,2 % teže (po 21-ih dneh). Vsebnost suhe snovi je počasi naraščala od 5,06 % do 6,92 % pri 5 °C (v obdobju 28 dni) in od 5,06 % do 6,26 % pri 10 °C (v obdobju 21 dni). Ugotovljena je bila majhna, statistično neznačilna razlika v suhi snovi paradižnikov med obema temperaturama. Spremembe skupnih kislin so bile med skladiščenjem relativno majhne. Po sedmih dneh so skupne kisline začele upadati pri obeh temperaturah. Med paradižniki, skladiščenimi pri različnih temperaturah, tudi ni bilo statistično značilnih razlik v obarvanosti kože.

Ključne besede: *Lycopersicon esculentum*, paradižnik, skladiščenje, temperatura, izguba teže, barva, kemična sestava

INTRODUCTION

Tomato is one of the most widely used food crops in world vegetable economy (Chapagain and Wiesman, 2004). In Slovenia, tomato plants are being grown in almost every home garden as well as in commercial operations (Žnidarčič et al., 2003). Tomato fruits still live and respire after harvesting, however their quality and appearance change during post-harvest handling.

Shelf life is defined as the period in which a product should maintain a predetermined level of quality under specified storage conditions (Shewfelt, 1986). A number of chemical and physical processes take place in vegetables during shelf storage. Also, quality of most fruits and vegetables is affected by water loss during storage, which depends on the temperature and relative humidity conditions (Perez et al., 2003). Hardenburg et al. (1986) mentioned, that storage under low temperature has been considered the most efficient method to maintain quality of most fruits and vegetables due to its effects on reducing respiration rate, transpiration, ethylene production, ripening, senescence and rot development. Temperature plays an important role in maintaining post-harvest quality of tomato fruits, too (Ball, 1997). The effect of storage temperature on physiochemical quality and quantity changes in tomatoes, varies with cultivar (Abou-Aziz et al., 1976), exposition time (Hobson, 1981) and harvesting conditions (Autio and Bramlage, 1986).

Tomato can be stored at ambient temperature for a period of up to 7 days. It is generally agreed that for longer period ripe tomato can be stored at a temperature of 10-15°C and 85-95 relative humidity (Shewfelt et al., 1987; Castro et al., 2005). At these temperatures chilling injury and ripening are minimal. However, careful handling of fruits during their storage is essential to avoid bruises and injuries. Decay organisms enter through such breaks in the skin.

Correct temperature management is also important for the consumer. Tomato should not be stored in the refrigerator. Refrigerating a tomato will reduce its flavour by approximately 30% (Ressureccion and Shewfelt, 1985). Flavour quality of tomatoes is largely determined by the sugar (estimated by soluble solids content) and acid composition of the fruit (Moretti et al., 1998). For example, the cold temperature will convert the sugars to starch. It will also cause its firm texture to turn pulpy (Adegoroye et al., 1989; McDonald et al., 1999).

Tomato colour is another important factor in the consumer preference of tomatoes (Thorne and Alvarez, 1982; Batu, 2003). The term colour is based on human perception of light and refers to one narrow band of the electromagnetic spectrum, called the visible spectrum (Hendry and Calkins, 1998). The colour of a ripe tomato is determined by the ratio of two pigments, lycopene and β-carotene (Hobson and Grierson, 1993). Colour can be commonly determined instrumentally because it gives more accurate information than other methods (Bakker et al., 1986). The most common instrument used is a colour differences meter and a model of the Minolta Chroma Meter (Anon, 1993).

In Slovenia, very little research has been done to identify the optimum environmental conditions for extending post harvest life of tomatoes. Tomato has potential to be developed as an exported crop in Slovenia. Due to the long distance transportation, optimum temperature might be needed for storage life extension.

During the 2005 season, study was conducted to evaluate the effectiveness of holding fresh tomato fruits in different storage temperatures of 5 ^{o}C and 10 ^{o}C to extend their post harvest life and maintain fruit quality parameters (weight loss, skin colour, soluble solids and titratable acidity).

MATERIAL AND METHODS

Tomato plants (*Lycopersicon esculentum* Mill.) used for the study were indeterminate tomato cv. 'Malike' (Clause Tezier). Plants were grown at the Experimental Station of the Biotechnical Faculty in Ljubljana in matted rows with 60 cm between rows, 40 cm on the row, and 1 m between plots. Transplants were planted in an open field in May. Standard agricultural practices were adopted uniformly according to crop requirements. Thirty of the tagged fruits per plot were harvested on the same day when they reached the middle-red ripe stage. Maturity of middle-red ripe stage fruit was determined in the field using subjective evaluations of fruit size, position on the plant, smoothness of fruit shoulder and by observation of locular development in some representative fruit (Kader and Morris, 1975). After harvest fruits were held overnight at about 10-15 ^{o}C and transported the following day to the Laboratory of plant food technology located at the Department of Food Science and Technology. Upon arrival at the laboratory, individual tomatoes were evaluated for initial quality. Only fruit free of apparent mechanical injuries, insect damage or disease were selected and placed on cardboard trays. The diameter of individual fruits were between 60 and 65 mm.

Fruits were randomly divided in two lots and stored for 28 days at 80-85 relative humidity to simulate a commercial storehouse situation. The first lot was stored at 5 ^{o}C and the second one at 10 ^{o}C. The temperature of storage rooms were controlled using a single point thermostat. Relative humidity inside the cold chambers was manually measured daily using wet bulbs/dry bulbs device and was maintained by spraying water when necessary.

The tomatoes were analysed five times during storage from October 10th to November 9th 2005. All measurements were done in triplicate. Weight loss, skin colour, soluble solids and titratable acidity, were examined every seven days.

Weight loss was evaluated by the difference in fruit weight on the first day of the experiment and each sampling. The weight of fruits was recorded using a Mettler balance model Toledo PB 602.

Skin colour was measured on three points of the fruit surface; on the shoulder, at the equator, and at the base. Colour was measured using a portable Minolta Chroma Meter (Minolta 200b) with LCH model calibrated with standard white plate (CY=93.8, x=0.3164, y=0.3208). Colour was expressed in coordinates *L*, *a* and *b*. Three readings from each fruit were averaged prior to data analysis.

Soluble solids concentration (Brix was noted in percentage) of the expressed juice was determined using a hand-held Atago PR1 refractometer (brix range 0–32% at 20 °C).

A 10 ml sample was used for determination of acidity by titrating with 0.1 M NaOH. Titratable acidity was calculated as g/l citric acid.

The data from all evaluations were subjected to multifactor ANOVA (Statgraphics) to compare quality parameters and storage time. Fisher's least significant difference (LSD) was used to discriminate among the means.

RESULTS AND DISCUSSION

The tomatoes stored at 5 °C and those stored at 10 °C differed from the freshly harvested tomatoes in the intensity of measured parameters. The storage life of tomatoes was determined as 21 days at 10 °C, after that time the peel of the fruits was turning brown and fruits began to decay. However, from the second group, storage life of tomatoes at 5 °C was 28 days.

Weight change was related to temperature and storage time. Post-harvest weight change in vegetables is usually due to loss of water through transpiration. This loss of water can lead to wilting and shrivelling, which both reduce market value and consumer acceptability (Ball, 1997). Weight loss of tomato was almost linear at both the storage temperatures (Figure 1). As expected, fruits stored at 10 °C lost weight faster than those stored at 5 °C. The intensity of weight loss during storage in the first week did not differ between the different temperatures. In both cases the weight loss increased more rapidly after seven days. At the end of the storage period the fruits stored at 5 °C experienced a weight loss of 13.6 % (after 28 days), while those stored at 10 °C showed values of 14.2 % (after 21 days). Lower temperature can also prevent weight loss.

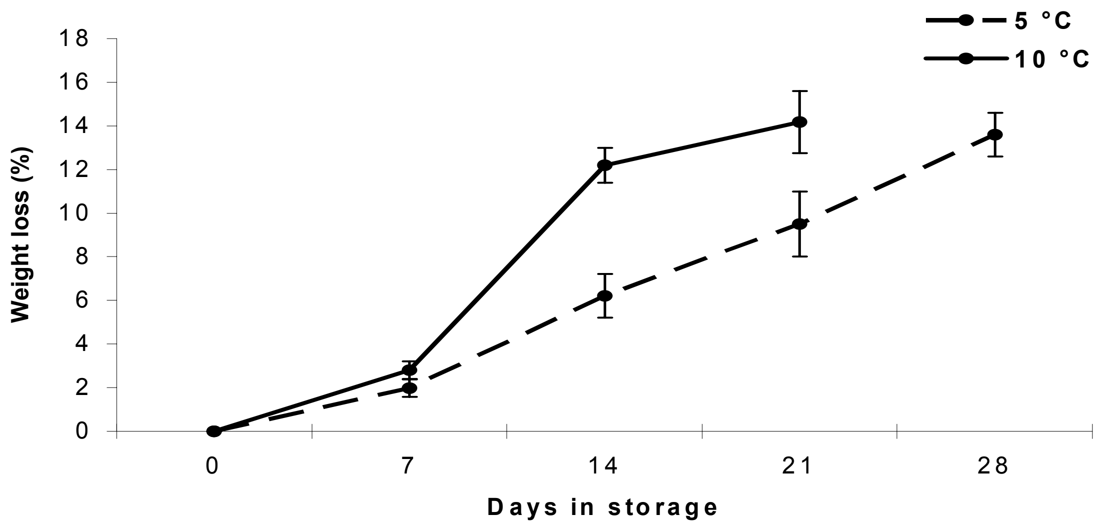

Figure 1: Changes in weight loss (%) in tomato cv. 'Malike' stored in different temperature conditions. Vertical lines represent standard errors of the means.

The fruit's content of soluble solids remained relatively constant during the post-harvest period up to 21 days (Figure 2). Soluble solids increased slightly from 5.06 % to 6.92 % at 5 °C (during the 28 day period) and from 5.06 % to 6.26 % at 10 °C (during the 21 day period). Although soluble solids content was slightly higher in fruits at 10 °C than in fruits from the other group no statistical significant differences for the two temperatures were found. At every stage of storage time, except at the initial storage period, the soluble solids content in fruits at 10 °C was always slightly greater than that found in the fruits at 5 °C. From the qualitative point of view, however, the soluble solids concentration reached an absolute maximum at the end of the storage period. According Salunkha et al. (1974), the increment of soluble solids is caused by the biosynthesis processes or degradation of polysaccharides during maturity.

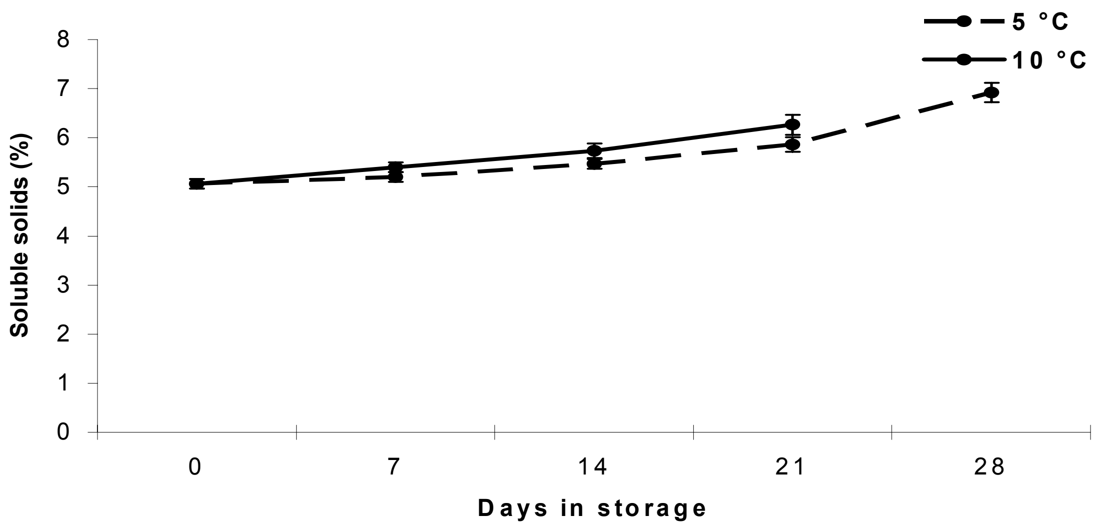

Figure 2: Changes in soluble solids (%) in tomato cv. 'Malike' stored in different temperature conditions. Vertical lines represent standard errors of the means.

Changes of titrable acidity during storage were relatively small (Figure 3). The quantity of titrable acidity content of fruits at the time of storage varied similarly for both temperatures. During the storage the acidity was increasing slightly in the first seven days. During this period the content of titrable acid increased by 0.08 g/l (at 5 °C) and by 0.07 g/l (at 10 °C) on average per day. Afterward the content of titrable acid started to decrease at both temperatures. The decrease of titrable acidity after seven days was almost linear in all cases although the rate of decrease was slightly higher in fruits at the 10 °C than at the 5 °C. At the end of the storage period there were no significant differences among acidity at both temperatures. These results agreed with those from Castro et al. (2005) presenting an acidity decrease with maturity evolution. Will at al. (1981) showed, that amount of organic acid usually decrease during maturity, because they are substrate of respiration. The decrease in titrable acidity after seven days coincided with a better score for sensory evaluation of stored fruits (data not shown).

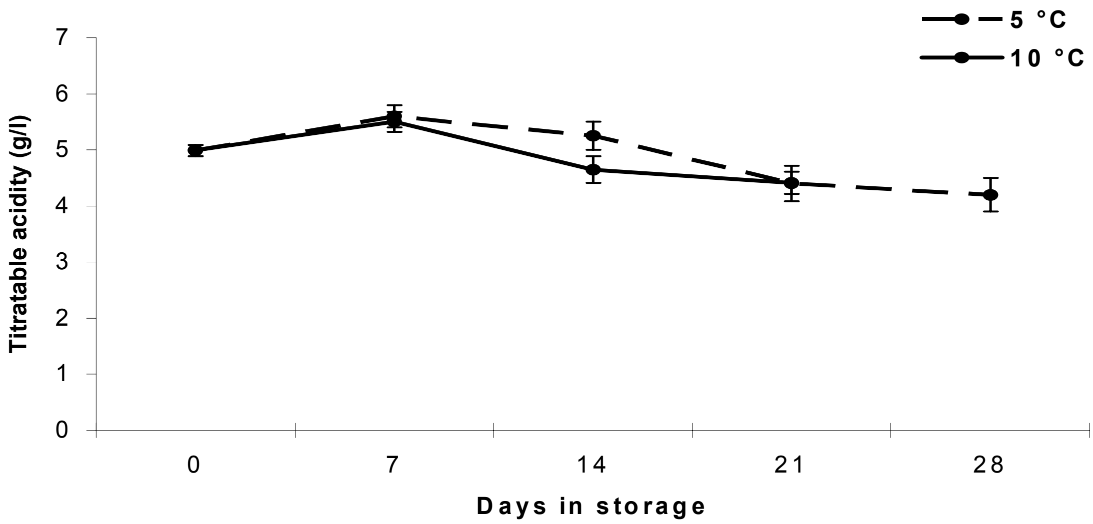

Figure 3: Changes in titrable acidity (g/l) in tomato cv. 'Malike' stored in different temperature conditions. Vertical lines represent standard errors of the means.

The colour components (*a*, *b*, *L*) of fruit did not significant vary among particular temperature groups (Table 1). The colour changed in fruit corresponds to a fall in chlorophyll and an increase in carotenoid synthesis (Pretel et al., 1995), reflecting the transformation of chloroplasts to chromoplasts (Leshem et al., 1993). The colour development rate of tomatoes increased with increase in maturity (Batu, 2003).

The colour development in fruits was similar at both temperatures. But on the contrary the colour components changes during the storage period. The colour value *a* which characterised the red colouring of the fruits (Auerswald et al., 1999), continued to increase clearly by 6.3 (at 5 ^{o}C) and by 6.6 (at 10 ^{o}C) during the first 21 days. Carotenes and xanthophylls contained in tomato, especially lycopene oxidize during the storage, gradually changed colour from bright red to dark brown. Our data is in accordance with Iwahashi et al. (1999). However, after 21 days all fruits reached their maximum red colour and although the fruits at the lower temperature tended to be less red than the fruits at the higher temperature, these differences were not significant.

Up to the first seven days, the *b* parameter, which shows yellow discolouration (Artes et al., 1999) remained initially unchanged at both temperatures. Fruit stored at 5 ^{o}C changed *b* value more slowly. However, after 21 days fruits reached their minimum of *b* value at both temperatures.

Luminance *L* measured changed rapidly at both temperatures over the first seven days of storage and remained at the same value after that. The intensity of luminance loss during storage in the first week slightly differed between the temperatures. *L* value was slightly higher in fruits at 10 ^{o}C than in fruits at 5 ^{o}C. According Hardenburg et al. (1986), storage under lower temperature reduces enzimatyc activities and the loss of luminance, resulting from normal ripening and storage process.

Table 1: Changes in colour components in tomato cv. 'Malike' stored in different temperature conditions

Storage days	**Colour components**					
	a		***b***		***L***	
	5 °C	10 °C	5 °C	10 °C	5 °C	10 °C
0	15.4 a	15.4 a	13.9 a	13.9 a	33.5 a	33.5 a
7	17.8 b	18.6 b	13.6 a	13.7 a	31.6 b	32.2 b
14	19.7 c	20.8 c	13.0 b	12.4 b	31.4 b	31.8 b
21	21.7 d	22.0 d	12.6 c	11.9 c	31.3 b	31.5 b
28	22.3 d	-	12.9 b	-	31.2 b	-

*Means within the same column followed by the same small letters are not significantly different (level of significance 5%)

CONCLUSIONS

The final results generally coincided with our anticipated results. 'Malike' tomato fruits were submitted to different storage temperatures and evaluated for their quality. The following conclusions could be drawn:

- weight loss of tomato fruit is closely related with the temperature;
- tomato fruit stored at lower temperatures have an acceptable weight loss;
- tomato fruit stored at lower temperature had more stability and greater storage life than fruit stored at higher temperature;
- where fruit is sold on a weight basis, loss of water means economic loss. Additionally, water loss reduces visual quality;
- the content of soluble solids progressively increased with storage at both temperatures, but earlier at 10 °C;
- the quantity of titratable acids, expressed as citric acid, slightly increased in both temperatures in the first seven days. Tomato fruits became less acidic after 14 days of storage. The relationship of titrable acidity content and temperature during the storage period of tomato fruits on higher and lower temperature was generally similar;
- the red colour appearence of tomato fruit was influenced by time of the development.

LITERATURE

Abou-Aziz, A.B., El-Nataway, S.M., Adel-Wahab, F.K., Kader, A.A. 1976. The effect of storage temperature on quality and decay percentage of 'Pairi' and 'Taimour' mango fruit. Sci. Hortic., 5: 65-72.

Adegoroye, A.S., Jolliffe, P.A., Tung, M.A. 1989. Texture characteristics of tomato fruits (*Lycopersicon esculentum*) affected by sunscald. J. Sc. Food Agr., 49: 95-102.

Anonymous 1993. Minolta, precise colour communication. Colour control from feeling to instrumentation. Hand book. Printed by Minolta camera Co. Ltd. Japan.

Artes, F., Conesa, M.A., Harnendez, S., Gil, M. 1999. Keeping quality of fresh-cut tomato. Postharvest Biol. Tech., 17: 153-162.

Auerswald, H., Peters, P., Brückner, B., Krumbein, A., Kuchenbuch, R. 1999. Sensory analysis and instrumental measurement of short-term stored tomatoes (*Lycopersicon esculentum* Mill.). Postharvest Biol. Tech., 15: 323-334.

Auito, W.R., Bramlage, W.J. 1986. Chilling sensitivity of tomato fruits in relation to ripening and senescence. J. Amer. Soc. Hort. Sci., 111(2): 201-205.

Bakker, J., Bridle, P., Timberlake, C.F. 1986. Tristimulus measurments (CIELAB76) of portwine colour. Vitis, 25: 67-78.

Ball, J.A. 1997. Evaluation of two lipid-based edible coatings for their ability to preserve post harvest quality of green ball peppers. M. Sc. Thesis, Blacksburg, Virginia, 89 p.

Batu, A. 2003. Determination of acceptable firmness and colour values tomatoes. J. Food Eng., 61: 471-475.

Castro, L.R., Vigneault, C., Charles, M.T., Cortez, L.A.B. 2005. Effect of cooling delay and cold-chain breakage on 'Santa Clara' tomato. J. Food Agr. Envir., 3: 49-54.

Chapagain, P.B., Wiesman, Z. 2004. Effect of potassium magnesium chloride in the fertigation solution as partial source of potassium on growth, yield and quality of greenhouse tomato. Scientia Hort., 99: 279-288.

Hardenburg, R.E., Watada, A.E., Wang, C.Y. 1986. The commercial storage of fruits, vegetables, and florist, and nursery stocks. Washington, Agriculture Handbook 66, 130 p.

Hendry, S.H.C., Calkins, D.J. 1998. Neuronal chemistry and functional organization in the primate visual system. TINS, 21: 344-349.

Iwahashi, Y., Horigane, A.K., Yoza, K., Nagata, T., Hosoda, H. 1999. The study of heat stress in tomato fruits by NMR microimaging. Mag. Res. Imag., 17(5): 767-772.

Hobson, G.E. 1981. The short-term storage of tomato fruit. J. Hortic. Sci., 56: 363-368.

Hobson, G.E., Grierson, D. 1993. Tomato. In: Biochemistry of Fruit Ripening (Seymour, G.B., Taylor, J.E. and Tucker, G., eds.). Chapman and Hall, London, pp. 405-442.

Kader, A.A., Morris, L.L. 1975. Ameloration of chilling injury symptoms on tomato fruits. J. Amer. Soc. Hort. Sci., 10: 324.

Leshem, Y.Y., Margel, S., Aurbach, D., Sofer, Y. 1993. Biophysical parameters of linoleic acid hydroperoxides as assessed by surface behavior and fourier transform infra-red spectrometry: possible pertinence to senescence. Plant Grow. Reg., 12(3): 263-272.

McDonald, R.E., Mccollum, T.G., Baldwin, E.A. 1999. Temperature of water treatments influences tomato fruit quality following low temperature storage. Postharvest Biol. Tech., 16: 147-155.

Moretti, C.L., Sargent, S.A., Huber, D.J., Calbo, A.G., Puschmann, R. 1998. Chemical composition and physical properties of pericarp, locule and placental tissues of tomatoes with internal bruising. J. Amer. Soc. Hort. Sci., 123: 656-660.

Perez, K., Mercado, J., Soto-Valdez, H. 2003. Effect of storage temperature on the shelf life of Hass avocado (*Persea americana*). Food Sci. Tech. Int., 10(2): 73-77.

Pretel, M.T., Serrano, M., Amoros, A., Riquelme, F., Romojaro, F. 1995. Noninvolvement of ACC and ACC oxidase in pepper fruit ripening. Postharvest Biol. Tech., 5: 295 302.

Ressureccion, A.V.A., Shewfelt, R.L. 1985. Relationships between sensory attributes and objective measurements of postharvest quality of tomatoes. J. Food Sci., 50: 1242-1245.

Salunkha, D.K., Jadhar, S.J., Yu, M.H. 1974. Quality and nutritional composition of tomato fruits influenced by certain biochemical and physiological changes. Qualitas plantarum, 24: 85-113.

Shewfelt, R.L. 1986. Postharvest treatment for extending the shelf life of fruits and vegetables. Food Tech., 40: 70-80.

Thorne, S., Alvarez, J.S.S. 1982. The effect of irregular storage temperature on firmness and surface color in tomatoes. J. Sci. Food Agric., 33: 671-676.

Wills, R.H.H., Lee, T.H., Graham, W.B., Hall, E.G. 1981. Postharvest: an introduction to the physiology and handling of fruit and vegetables. Kensington, New South Wells Press, 161 p.

Žnidarčič, D., Trdan, S., Zlatič, E. 2003. Impact of various growing methods on tomato (*Lycopersicon esculentum* Mill.) yield and sensory quality. Res. Rep., Biotech. Fac., Univ. Ljublj., Agric. issue 2, 81: 341-348.